Composites Fabrication and Industrial Applications

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Presentation Overview

- CFC-WVU: FRP Center of Excellence
- Corrosion Knowledge Base
- Why FRP (Fiber Reinforced Polymer) Composites
- FRP Composite Materials Manufacturing Methods
- Applications
- Degradation of FRP Composite Materials
- Commercialization Strategies
- Conclusions

Constructed Facilities Center West Virginia University (CFC-WVU)

- CFC is established in 1988 to bridge Univ.-Gov.-Ind. Efforts
- (10+2) Faculty, 6 Eng Scientists, 4 Staff, 35+ Grads
- Interdisciplinary: Civil, Chem., Elec., Indus., Mech.
- Aim:
  - To foster and conduct R & D vital to new constructions and rehabilitation of existing facilities
  - To promote and advance FRP composites for civil and military infrastructure applications
- FRP Center of Excellence (by DOT/FHWA in 1999) DOT/FHWA – United States Department of Transportation – Federal Highway Administration

What CFC-WVU Can Offer ?

- Technology training
- Material characterization
- Destructive/nondestructive evaluation
- Field monitoring & performance studies
- Product development
- Design and prototype manufacturing

Corrosion/Aging of Military Materials

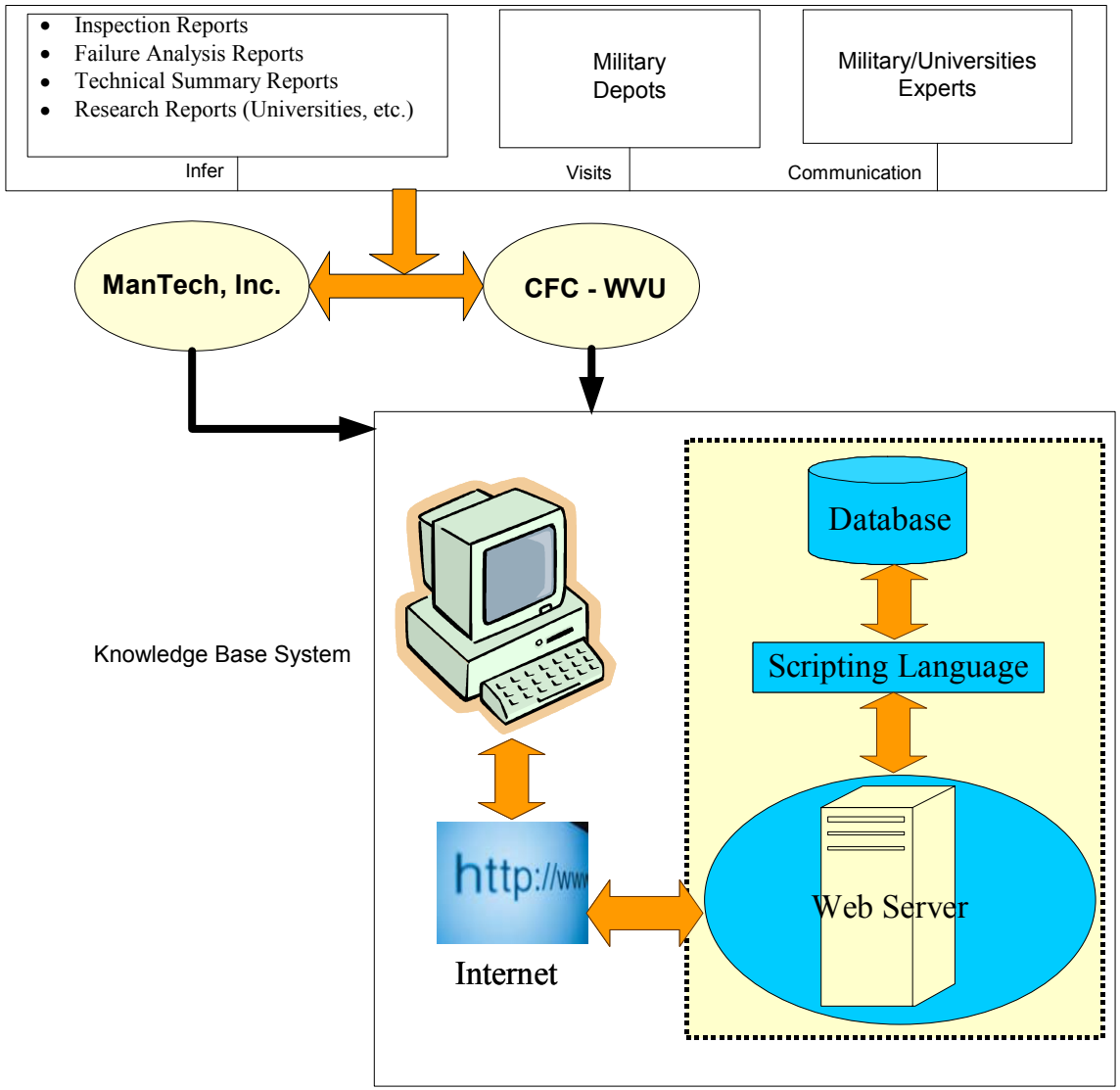
- Corrosion of military materials and systems is a serious problem. CFC-WVU has:

1. A joint venture with Management Technology, Inc. (ManTech, Inc.), Fairmont, WV on
   - Corrosion Website
   - Corrosion Knowledge Base
2. FRP composites R&D program as an alternative to conventional materials like steel, wood, or concrete

Development of Web-Based Corrosion Information Repository

- This is a Joint venture of:
  - CFC-WVU and ManTech, Inc.
- Address of corrosion website:
  - http://www.dodcorrosionexchange.org
- Features of the corrosion website are:
  - Taxonomy of Corrosion/Aging of military materials
  - Review of 600 research reports on corrosion/aging issues
  - Corrosion Dictionary

Corrosion Knowledge Base



Corrosion Knowledge Base (contd.)

- Searching for unclassified data on available weapon systems from DOD depots including:
  - Inspection reports
  - Failure analyses reports
  - Technical summary reports
- **Please contact CFC-WVU if you have the above information or need additional information at:**
  - **(304) 293-7608 ext. 2634**
  - **Hota.GangaRao@mail.wvu.edu**

Advantages/Limitations of Using FRP Composites

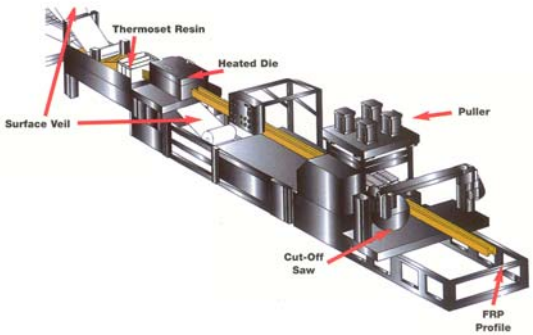
- Being accepted as replacements of traditional materials in many applications, because of:
  - Higher strength- and stiffness- to-weight ratios than steel, wood or concrete
  - Higher fatigue strength & impact energy absorption capacity
  - Better resistance to corrosion, rust, fire, hurricane, ice storm, acids, water intrusion, temperature changes, attacks from microorganisms, insects, and woodpeckers
  - Better flexibility
  - Longer service life (over 80-100 years)
  - Better non-conductivity
  - Lighter-weight leading to lower installation cost
  - Lower maintenance cost
- But, more expensive per unit weight

Our Goal

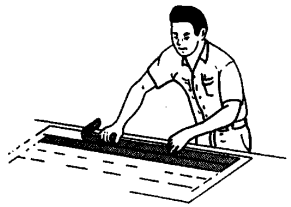
- Commercialization of Advanced FRP Composite Materials for Poles, Posts, Pipes and Panels
- Commercialization means "the cost–effective production and application of advanced materials to meet global market needs" - According to National Materials Advisory Board, National Research Council, 1993

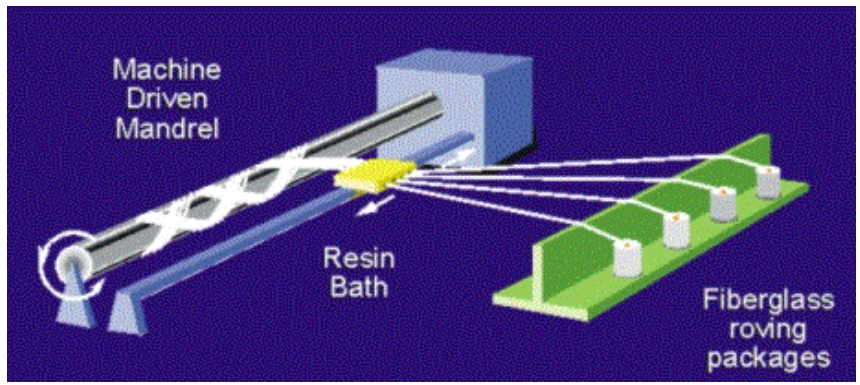
Note: Composite bridge decks from CFC-WVU designs coupled with BRP Inc.'s production and installation capability are costing about the same amount as concrete decks on a square foot area basis, i.e. about $30 /sq ft.

Manufacturing Methods



- Pultrusion
- Hand lay-up
- Compression molding
- Resin transfer molding/ Resin infusion molding
- Filament winding
- Injection molding

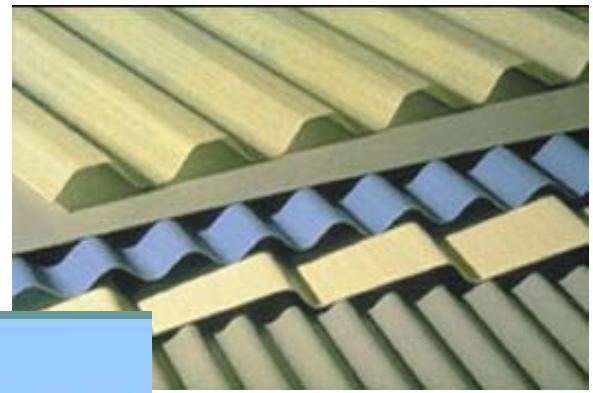




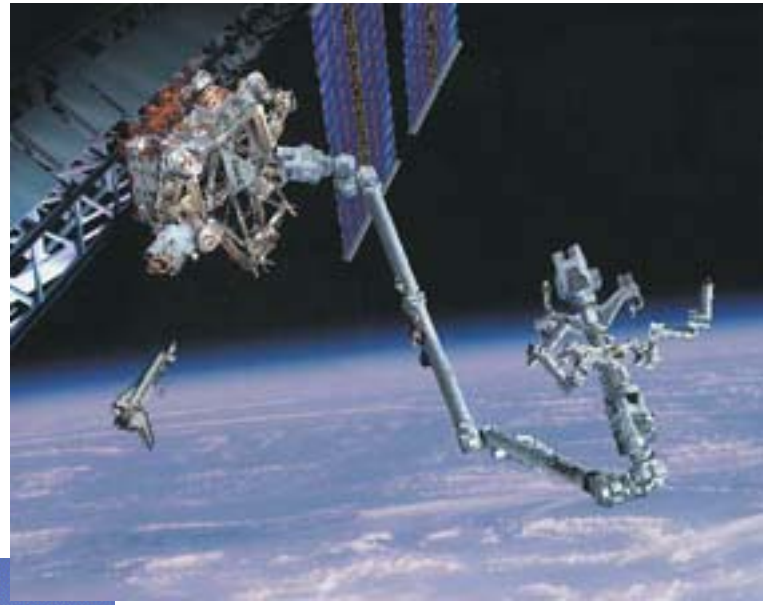
FRP Applications:
Poles, Posts, Pipes and Panels

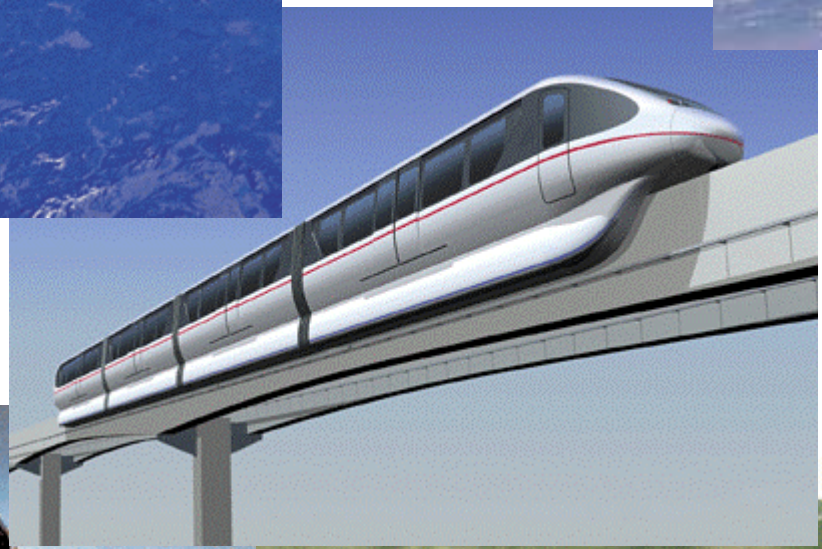
FRP Applications: Composite Panels

- For extremely wide range of applications: wall, floor, roof, bridge decks, marina……

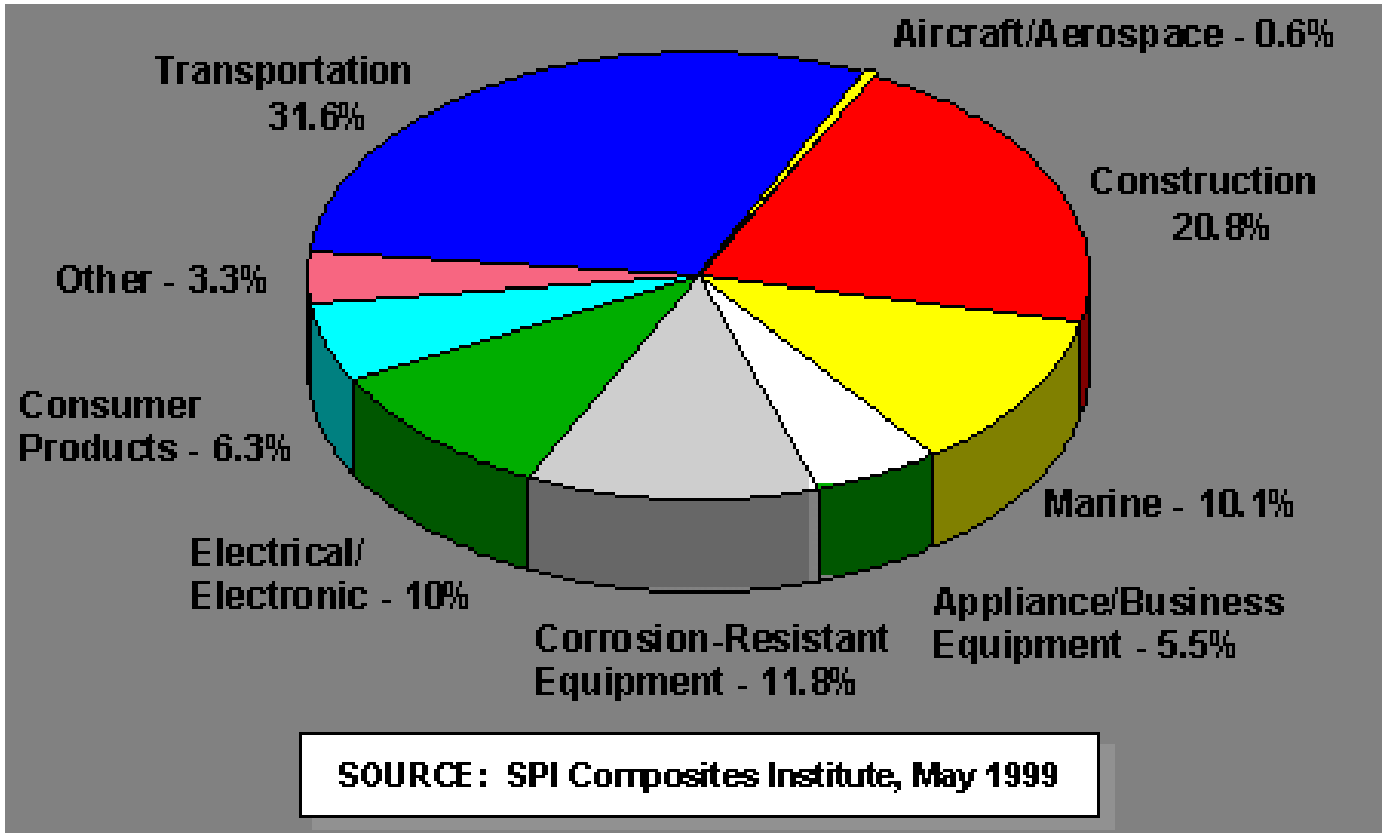


More Applications





Current Markets and Applications



U.S. FRP composites: 4.2 billion pounds in 2002

Prospective Market: Poles

- 130 million utility poles in-service in USA
  - 98% chemically treated wood poles
  - ~4 million poles need replacement per year
  - ~90,000 poles in WV
- $4 billion treated wood poles annually
  - $2.8 billion for replacement
  - $1.2 billion for new construction

Prospective Market: Posts

- 36 million highway signposts are in-service with an annual replacement of about 2 million posts in U.S., generating a market of $100 to 200 million
- WVDOT uses approximately 50,000 wood and 200,000 steel guardrail posts annually

Prospective Market: Pipes

- Extensive pipeline infrastructure in service in U.S.
  - 161,189 miles liquid pipelines
  - 307,809 miles natural gas transmission pipelines
  - 1,100,855 miles natural gas distribution pipelines
  - 2,000,000 miles water and sewage pipelines
- Over 50,000 miles of new natural gas transmission pipelines are being built in the 2001-2010 timeframe at a cost of over $80 billion in North America

Mechanical Property Degradation Factors for FRP Composites

Mechanical properties of polymeric materials depend on:

- Primary and secondary chemical bonds in the polymer chain
- Chemical and physical structure of the polymer (dislocation energy of primary, secondary bonds and other components of chemical structure such as steric factors, resonance stabilization)
- Morphology, orientation and sample size, contaminants and biological factors
- Additives (lubricants, plasticizers and reinforcing fillers) and modifiers
- Time and temperature
- Moisture (water, acidic and basic pH) and pressure
- Nature of stress (sustained and transient)

Mechanisms of Degradation

- Random chain scission
- Depolymerization
- Cross-linking
- Side group elimination
- Substitution
- Reaction of side groups among themselves

Effects of Moisture

- Water penetrates a GFRP through two processes:
  - Diffusion through the resin
  - Flow through cracks or other material flaws

Chemical Action of Water

- Resins experience volume changes relative to glass because of polymerization shrinkage, thermal shrinkage on cooling from cure and swelling by absorbed liquids such as water
- In composites exposed to water, decrease in chemical energy takes place due to hydrolytic scission of ester groups
- In FRP two types of chemical bond are susceptible to hydrolysis:
  - siloxane linkages between fiber and coupling agent and within the coupling agent
  - ester linkages occurring in polymer resins, in anhydride-hardened epoxies and others
- Moisture absorption results in softening of brittle matrix and may increased toughness and reduced strength and modulus

Effect of Temperature

- Temperature affects the rate of moisture absorption as well as mechanical properties of a composite
- Decrease in temperature leads to possible increases in:
  - 1. modulus
  - 2. tensile and flexural strength
  - 3. fatigue strength and creep resistance
  - 4. adhesive strength
- Decrease in the following properties is possible with temperature reduction:
  - 1. elongation
  - 2. deflection
  - 3. fracture toughness and impact strength
  - 4. compressive strength
  - 5. coefficient of linear expansion
- Lower coefficient of thermal expansion of glass fibers over the matrix, produces residual stresses within the material microstructure during temperature drop

Commercialization Strategies

- **Objective:**
  - Near term goal is to mass produce high volume and high quality structural composite components and systems at competitive prices.
  - Long term goal is to expand into mass production, sales, marketing, and distribution of other products currently or conventionally made of commodity materials like concrete.
- **Dual-use applications**
  - To meet government /public works needs
  - To meet civilian /military needs
- **Phases in commercialization process:**
  - Technology base development (ready from CFC)
  - Product development & demonstration (partially ready)
  - Early commercialization
  - Full commercialization
- **Partnership roles**

Conclusions

- **Advantages of Web-based Corrosion Knowledge Base**
  - DOD personnel and DOD contractors can access information on the Internet.
  - Duplication of effort to combat different facets of corrosion affecting weapon systems will be avoided.
  - Corrosion prevention methods used by different personnel can be accessed in an effective way.

- **Advantages of using FRP composite materials**
  - Profitability
  - Durability
  - Flexibility
  - Maintainability